ing equipment, and pesticides have been dramatic over the past two decades and should continue into the future. Many believe that growing crops using conservation tillage is more sustainable on sloping cropland than a conventional moldboard plow system that buries the protective crop residue and leaves the soil surface vulnerable to severe soil erosion. ■

How Research Improves Land Management

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by L.D. Meyer, Agricultural Engineer, National Sedimentation Laboratory, ARS, USDA, Oxford, MS; and K.G. Renard, Hydraulic Engineer, Aridland Watershed Management Research Unit, ARS, USDA, Tucson, AZ

Productive soil is one of our Nation's greatest natural resources, so maintaining land productivity and preventing environmental degradation from soil erosion are high-priority national goals. A century ago, essentially no soil conservation research was conducted in the United States; today America is the world leader. During the same period, American farming methods have changed tremendously, and soil erosion problems have expanded and intensified. The part that research has played in improving management of our billion acres of productive land is an important part of our agricultural history.

Rainfall and Erosion

Another key resource that makes land productive is rainfall. Between 100 million and 1 billion gallons of rain fall annually on each square mile of U.S. land. This water is essential for crop production, but it may also cause problems such as soil erosion and flooding.

Rain falls as drops averaging less than one-eighth inch in diameter, but each drop strikes the land as a tiny bomb. Every year throughout most of the United States, more than a quadrillion (1,000,000,000,000,000) drops strike each square mile of land with the impact energy of thousands of tons of TNT. The impact energy of rain falling on the State of Mississippi, for example, annually equals the energy of a thousand 1-megaton bombs or 1 billion tons of TNT.

When raindrops fall on unprotected soil, they start the erosion process. These drops detach soil that is then transported downslope by runoff, the rainfall excess that is not absorbed by the soil. Not only does this runoff carry raindrop-detached soil and cause additional erosion itself, but the water is lost to crop production. Runoff from fields and forests to streams and rivers in Mississippi, for instance, averages nearly 20 trillion gallons annually.

Wind Erosion

Although the major erosion problem in most parts of the United States (and the focus of this chapter) is erosion caused by rainstorms, wind erosion is also a serious hazard. Wind erosion results from strong winds blowing across inadequately protected soil, and it usually is worst during droughty conditions. The famous Dust Bowl of the Great Plains during the 1930's was a period of unusually severe wind erosion.

Each drop of rain strikes like a tiny bomb. Every year in the United States, more than a quadrillion raindrops strike each square mile of land with the impact energy of thousands of tons of dynamite. *USDA 91BW0679*

Erosion Research

In the 1930's, the Nation's rapidly deteriorating land resources—and the highly conspicuous Dust Bowl—prompted the Federal Government to launch a major soil conservation research effort. Its purpose was to learn more about how rainfall, runoff, and wind affect erosion in the United States. This research has been largely supported by Federal and State funds through USDA and State agricultural experiment stations.

The primary concern during the early years of research was the consequences of excessive soil erosion on crop yields. By the end of the 1930's, research data plus farmers' experiences showed conclusively that excessive erosion seriously reduces productivity, so researchers proceeded to evaluate erosion rates for typical land use situations and to develop erosion control technology.

During the 1940's and 1950's, measurements of different agricultural conditions identified those that permitted serious erosion and those that were effective in conserving soil. Erosion-control practices such as terracing, stripcropping, year-round vegetative cover, and windbreaks were developed to fit farming procedures and equipment. Other research was directed toward predicting erosion rates for specific soil, topography, cropping system, and climatic conditions of individual fields. These efforts culminated in development of the USLE (Universal Soil Loss Equation) and the WEE (Wind Erosion Equation). Both were developed by scientists with USDA's Agricultural Research Service (ARS) and Soil Conservation Service (SCS), the USLE in cooperation with Purdue University and the WEE with Kansas State University.

USLE, RUSLE, and WEE

The USLE and its recent revision (RUSLE) quantify annual soil loss as the product of six factors that represent the following:

- Rainfall/runoff erosiveness
- Soil erodibility
- Slope length
- Slope steepness
- Cropping and management practices
- Supporting conservation practices

Generally, USLE values show that a year of rainstorms in the Southeastern United States totals twice the erosiveness of those in the Midwest. High silt soils with low organic matter are 50 percent more erodible than those with high organic matter and twice as erodible as soils with high clay or sand content. Fields of 7-percent slope have twice the erosion of fields with 4-percent slope, and 11-percent slopes have four times

An increased understanding of fundamental soil erosion principles and processes can help in selecting effective soil conservation practices, as on this farm near Philadelphia, OH. The pond catches runoff from the land above and helps protect the land below from serious soil erosion.
Erwin Cole/USDA OH-60961

the erosion of 4-percent slopes. And no-till corn has only half the erosion of no-till soybean and one-fourth that of conventionally tilled corn.

By selecting appropriate USLE/RUSLE values for specific situations, conservation planners can recommend production methods for individual fields that limit soil losses to rates that maintain productive potential of the land indefinitely.

Similarly, the WEE predicts wind erosion rates as the function of five factors that represent the following:

- Soil erodibility
- Soil ridge roughness
- Climate
- Field length
- Vegetative cover

Since the USLE and WEE were first introduced, their systematic approach has had a tremendous effect on erosion technology and conservation planning. Their equations and adaptations of them are used worldwide.

Understanding Erosion

During the 1960's and 1970's, scientists emphasized fundamental research designed to better understand the principles and processes of soil erosion by water and wind. They analyzed and quantified the companion but very different processes of raindrop-caused erosion and runoff-caused erosion. The aerodynamics of wind in relation to soil detachment and transport were defined.

The effects of different types of plant cover, tillage, and cropping systems were evaluated on erosion plots and watersheds, using rainfall simulators and wind tunnels. Various types of conservation tillage were developed, evaluated, and found to greatly reduce both water and wind erosion from land during intensive cropping. Scientists also identified and quantified soil and sediment characteristics that affect erosion rates and sediment pollution potential.

Using a rainfall simulator, ARS scientists conduct erosion research by collecting and analyzing the runoff.
Tim McCabe/USDA 0887X0840-33

Model Development

During the 1980's, the knowledge gained from past experiments and fundamental studies provided the basis for developing mathematical models to describe erosion over a wide range of specific conditions and to improve erosion prediction and control methods. About the same time, the environmental movement gave impetus to an expanded research effort to understand off-site effects of soil erosion and the potential for chemical pollution resulting from it. Models such as CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems) were formulated, which included hydrologic, erosion, pesticide, and nutrient components. Such models incorporated major advances in describing the physical processes involved in soil erosion, sediment transport and deposition, and chemical transport.

Most recently, the WEPP (Water Erosion Prediction Project) model has been developed by ARS, SCS, the FS, the Department of the Interior's Bureau of Land Management, and cooperating universities as the next-generation water-erosion prediction model to replace the USLE/RUSLE. The more versatile WEPP model incorporates many of the scientific advances that have been made since development of the USLE and is based on the principles and processes of soil erosion by water.

A similar effort by ARS, SCS, and university cooperators is underway to improve the predictive capability for wind erosion, culminating in the WEPS (Wind Erosion Prediction System) model. This model is based on the fundamental principles of wind erosion physics associated with climate, soil, topography, and cropping/management systems that affect sediment detachment, transport, and deposition.

Soil Conservation Practices

An increased understanding of fundamental soil erosion principles and processes also helps in selecting effective soil conservation practices for specific land conditions. Effective erosion control involves the following:

- Dissipating raindrop, runoff, and wind-induced erosive forces on nonerodible materials rather than erodible soil
- Reducing the amount of runoff
- Slowing runoff or wind velocities
- Improving soil characteristics that resist the erosive forces
- Preventing massive gully and channel erosion
- Decreasing wind access to barren soil

By identifying the processes that are causing the primary erosion hazards, the best individual management practice or combination of practices (BMP's) may be selected for a particular situation.

Cropland Erosion Control

For conditions where serious erosion is due primarily to raindrop impact or intense winds, protection of the soil surface by plant residue mulches or growing vegetation can be very effective. Keeping the soil covered during periods of critical erosion hazards is especially important, so minimizing tillage and using cropping systems that disturb land only during those times of the year when major rainstorms or windstorms are uncommon should be emphasized. Use of close-growing vegetation or narrower crop rows instead of wide-row crops may also help reduce erosion.

On land where the topography and cropping system are susceptible to serious erosion by concentrated runoff, runoff reduction and management deserve high priority. Practices such as dense vegetation and plant residues that reduce soil surface sealing and increase infiltration will be very effective in reducing runoff. Runoff management can be achieved by routing runoff around the slope at nonerosive velocities using practices such as terraces and row-grade control. When runoff is so great that it cannot be managed in this way, detention structures and/or vegetated waterways are effective.

Erosion from soils that erode as very fine sediment is very difficult to control once the soil is detached. Therefore, vegetation and mulches that provide good soil cover to prevent soil detachment are most effective. In contrast, coarse-textured sediment can be more easily trapped by vegetation, rough-tilled land, contoured rows, terraces, or detention structures. Even with coarse-textured soils, preventing detachment by soil cover is still the most desirable practice, but these sediment-trapping practices will also help prevent major losses.

Soil losses from land with steep or long slopes are difficult to control once the soil has been detached, so maintenance of good soil cover to prevent raindrop and runoff erosion is very important. In contrast, soil losses from land with relatively flat slopes can often be reduced by management practices, such as dense vegetation and graded rows, which slow or store surface runoff.

Effective conservation practices for land subject to wind erosion include vegetative cover (especially stubble from the previous crop), windbreaks and wind barriers, rough and cloddy soil surfaces, and tillage perpendicular to the prevailing wind direction.

Other Erosion Problems

Although reduced productivity is the most widespread consequence of excessive erosion, soil conservation research is not limited to hazards caused by rainstorms or windstorms on cropland. Research is also underway on rangelands, where precipitation is often inadequate for maintaining sufficient vegetation to protect against wind and water erosion losses of the limited soil research sources. Other studies concern erosion from irrigation of sloping fields, on forest lands, and on nonagricultural land such as urban areas, construction sites, highway slopes, and surface-mined land.

Farming Changes and Research on New Problems

Agricultural production methods have changed tremendously since the days of the horse-drawn plow, and many of these changes have increased erosion hazards. Today's heavy mechanized equipment compacts soil and reduces infiltration. Large implements work best on long fields devoid of conservation practices that would hinder their operation, and they operate better when troublesome surface residues have been removed or buried. Absence of horses and other animals on many farms means that hay is no longer needed, so continuous row crops are grown where rotations and pastures once grew. Yet intensive use of agricultural land is necessary because American agriculture is feeding several times more people today than at the beginning of the 20th century.

Research has demonstrated that cropping practices such as conservation tillage (see Chapter 3) can enable farmers to use modern farming methods and still control erosion. However, increased residues and pest accumulations present with conservation tillage require increased use of agricultural pesticides, an environmental tradeoff. Many cropping systems and supporting practices that benefit soil conservation are not considered economically feasible for today's farming situations.

Researchers have shown that crop production can continue without excessive soil losses on much of our Nation's erodible land if farmers adopt conservation cropping systems and properly manage their soil and water resources. However, because of circumstances that are often beyond farmers' control, only small reductions in wind and water erosion have come about in recent decades. Current research is focusing on developing conservation practices that are compatible with current agricultural methods; that enable farmers to make a reasonable profit; and that control soil losses, runoff, and other environmental hazards.

Soil erosion annually produces several billion tons of sediment from U.S. land. Such sediment has always been and continues to be, by volume, our Nation's greatest pollutant. Past erosion has caused major losses of our Nation's soil resources, but consider "what might have been" if we had not developed a land stewardship ethic and embarked on a soil conservation research effort early in this century.

The examples given show that soil conservation research during the past half century has produced a good understanding of the complex soil erosion process and provided effective technology to predict and control soil erosion. These advances were accomplished through the efforts of dedicated Federal and State researchers and action agency specialists. Because of their expertise, the last several generations have experienced remarkable developments in soil conservation technology. Erosion prediction and control methods are now available for most soil, topographic, and rainfall situations, and even better technology promises to emerge from current studies. Certainly, soil and water conservation research must be an important component of all future efforts to conserve our productive soil resources, prevent damage from eroded sediment, and maintain environmental quality. ■

Soil Changes and New Ways To Monitor Them

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What Are Soils?

Thousands of soils join to form the pedosphere, the thin outer covering of the surface of the Earth. Soils share the surface layer of the Earth with plants, animals, and people. Soils are protective living geomembranes through which energy, nutrients, and water pass as they nourish land-based life.

Soils are the product of ecosystems and a recorder of our Earth's history. By monitoring soil processes, we can detect patterns and relationships significant to our understanding of ecosystems and the environments in which they exist.

Soil Processes

Ecosystems can be visualized as dynamic segments of the environment, involving the biology of plants, animals, and microorganisms; the chemistry and